The Russian war of aggression against Ukraine as an opportunity for the green transition in Europe

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Abstract

This thesis will focus on the evolution of green hydrogen as a sustainable energy and the impact that the Russian war of aggression against Ukraine in February 2022 had in the development of this energy in the European landscape. This armed conflict triggered an energy crisis in the region, forcing states to take immediate action to recover their energy independence and sovereignty from Russian fossil-fuels. As a consequence, the REPowerEU Plan was launched as a way to diversify energy sources, improve energy efficiency and foster renewable energies. Green hydrogen is a key component to achieve the last objective as it is an energy source that is produced from other renewable sources and does not emit greenhouse gases. However, there are still numerous challenges to overcome related to the costs of production, required infrastructure and loss of energy during transportation. The aim of this research is to explore how Germany and France, being the two most important economies in the European Union have faced the challenges that the 2022 energy crisis brought, using the energy trilemma framework created by the World Energy Council, which evaluates energy security, equity and sustainability. Key findings show that both countries have implemented stricter green hydrogen policy measures in response to the 2022 energy crisis, but while Germany's policies in general were more ambitious, they also gave importance to the import of other sources of hydrogen energy that are not so sustainable as green hydrogen, while France's policies were more focused on green hydrogen produces mostly locally.

Keywords: *green hydrogen, Russia-Ukraine war, green energy transition*.

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Introduction

February 2022 will be remembered by people all over the world for the Russian war of aggression against Ukraine. The conflict started abruptly and, even though some people thought it would finish soon and that the international community´s intervention and sanctions against Russia would accelerate the end of the conflict, the reality is that almost two and a half years have passed, and the international armed conflict plagued of the most terrible crimes is still ongoing.

The conflict did not only show its consequences to the Ukranian citizens, but it has also created different crises all over the world, being the European energy crisis one of the worst. The war triggered a crisis in the prices of energy, as Russia was one of the main providers of oil and gas to many countries of the EU. This way, prices escalated abruptly, reaching an all-time peak in August 2022, what had a direct impact on almost all the economic activities and households across the region and the cost of living started to spiral out of control (European Council).

As a consequence, the EU had to look for alternative options to phase out from Russian fossil fuel energy as soon as possible and recover its energy sovereignty through the promotion and implementation of renewable energies. This way, the REPowerEU Plan was launched in May 2022, to help the block diversify the energy supply and phase-out from Russian fossil-fuel dependency, improve energy efficiency and boost renewable energy implementation from various sources, for instance, green hydrogen. This energy source is an extremely promising green energy for the green transition to combat climate change, as it does not produce air pollutants or greenhouse gas emissions, but still needs great research and investments (The Federal Government of Germany).

1.1 Research aim

This paper will analyze the situation of hydrogen energies in general nowadays, and green hydrogen in particular, going through the potential it offers as a tool to combat climate change and foster decarbonized economies. Additionally, it will seek to analyze the challenges this new source of energy presents to be implemented in a large-scale scenario. Finally, it will focus on Germany's and France's strategies to foster and implement green hydrogen in the energy scheme of both countries, comparing the existing policies before and after the Russian invasion of Ukraine. This way, both responses will be compared to find similarities or differences between countries that are the main economic powers in Europe, but that have diverse energy schemes, to the crisis started after February 2022. To accomplish the proposed analysis, the energy trilemma framework from the World Energy Council (World Energy Council 2024, **76**) will be used to interpret the energy security, equity and sustainability proposed by both models to compare them in a thorough way.

1.2 Methodology

To conduct the proposed research, a combination of document analysis and case studies will be produced. Document analysis consists of the evaluation of a variety of documents previously filtered and selected to find understanding and insights related to a specific topic of research (Bowen 2009, 27). In this case in particular, different sources of information, including policy papers, scientific reports, government reports or communications and academic papers will be used as primary and secondary sources of information and analysis.

Moreover, two case studies related to the green hydrogen strategies adopted by Germany and France will be conducted with the objective of comparing both countries' answer and reaction to the REPowerEU Plan as a way to abandon the dependency of the EU from Russian fossil-fuels.

The reason to choose these two countries to conduct a comparative analysis is rooted on the size of the economies of both countries, as they are the most powerful ones in the EU, added to the largest energy consumers. However, both countries have very different energy schemes, as before the war Germany was highly dependent on Russian fossil-fuel imports, while France had higher energy independence based on the use of nuclear power, which Germany phased-out in April 2023 (Federal Office for the Safety of Nuclear Waste Management of Germany 2024).

1.3 Main hypotheses

This research will have two main hypotheses, the first one will state that both countries, Germany and France, needed to improve and expand their green hydrogen policies as a consequence of the energy crisis initiated after the Russian war of aggression against Ukraine in February 2022. While the second hypothesis will state that Germany needed to take stricter and more ambitious green hydrogen policies than France to tackle the energy crisis, based on its previous dependence on Russian fossil-fuels.

The objective of this research will be to study the impact that an external shock in geopolitics, such as the energy crisis of 2022 caused by the Russia-Ukraine war, had in the national policy sphere of Germany and France. The aim will be to contribute to improve and deepen the understanding of the opportunities and challenges that green hydrogen as a source of energy presents as a tool for the green transition, which the great majority of the countries around the world are facing nowadays.

The importance of this research is rooted in the advances that adverse geopolitical situations, like the outbreak of a war, can provide to the green energy transition, as countries are pushed to accelerate the adoption of renewable energies to gain back their energy independence and sovereignty. Consequently, great technological innovations take place as a reaction to these events, what represents an advancement for the ecological transition and decarbonization. Moreover, good case practices and policy development strategies can be later extrapolated from the German and French models to be implemented in different countries.

The results will provide better insight on the specific impacts of the war of aggression conducted by Russia against Ukraine, but also offer a broader understanding of the strategies and policies that could be implemented by the states to improve their energy systems using the energy trilemma framework in a rapidly changing world.

Literature review

This first chapter will explore the state of the art of hydrogen energies, focusing on green hydrogen production, going through the technologies needed, the diverse benefits that its use proposes as part of a sustainable transition, and also the challenges that implementing a new source of energy into the already existing energy scheme brings. Afterwards, it will analyze the impact that the Russian invasion of Ukraine had in terms of the energy crisis that shocked Europe, and how the implementation of green hydrogen has been proposed as one of the ways to phase-out from the Russian fossil-fuel dependency. Finally, the energy trilemma framework adopted by the World Energy Council will be explained as the theoretical framework used to analyze Germany's and Frances's green hydrogen strategies.

2.1 Environmental concerns

It is unequivocal that human influence has warmed the atmosphere, ocean and land (IPCC WG-I 2021). Hence, the world is facing a major crisis related to the untamed levels of greenhouse gas emissions that are already bringing increasingly dangerous consequences to the environment, human health and living conditions in general (IPCC 2020). Consequently, emissions need to be reduced to net-zero within the next few decades to avoid a dangerous increase in global temperatures (IPCC 2020).

Fortunately, the green transition is becoming a reality, as renewable energies like solar panels and wind energy have decreased their costs up to 85% since 2010, complemented by a range of policies and laws that enhanced energy efficiency and accelerated the deployment of renewable energy (IPCC 2020).

Considering the urgency to achieve a low-carbon transition, global fossil fuel use will need to decline substantially by 2050 to limit warming to 2°C, and it must decline substantially by 2030 to limit warming to 1.5°C with no or limited overshoot (IPCC WG-3 2021, 698). Clearly, the environment needs all countries to take climate action urgently, as greenhouse gas emissions need to be reduced rapidly. Already, 131 countries covering 90% of global GDP have presented net-zero targets, and 46 countries have implemented or announced carbon dioxide emissions pricing or trading schemes (Hydrogen Council and McKinsey&Company 2022, 2).

2.2 What is hydrogen energy

As part of the green transition and decarbonization processes, 40 countries have presented national hydrogen strategies as an opportunity to decarbonize their economies, ensure energy security, and spur sustainable economic growth. Nowadays, there is not one stakeholder that denies the need for hydrogen energy to achieve net-zero emissions, including States, industries and consumers (Hydrogen Council and McKinsey&Company 2022, 2).

Green hydrogen is the most environmentally friendly way of hydrogen production, as it is a zero-carbon energy (Islam et al. 2024,460). However, green hydrogen is also known as the most cost-intensive form of hydrogen energy, what currently represents a disadvantage for its massive production. Nevertheless, green hydrogen is going through a cost reduction process as technology continues to develop (Islam et al. 2024, 460).

Hydrogen demand is estimated to rise seven-fold by 2050. Out of which two-thirds will be produced via renewable electricity and electrolyzers (World Bank Group and Hydrogen Council 2022, 9). IRENA estimates that clean hydrogen could account for 12% of final energy consumption by 2050 under a 1.5 °C global warming scenario (World Bank Group and Hydrogen Council 2022, 9).

Hydrogen energy is usually classified into different colours. These divisions depend on the source of the energy used to create it. Green hydrogen is the least polluting one, as it is produced by splitting water into hydrogen and oxygen using renewable electricity through a process called electrolysis, what generates very low or zero carbon emissions (Green Hydrogen Organization). However, there are plenty of hydrogen energies, which can be seen in Figure 1.

Figure 1 - Different Shades and Colours of Hydrogen for proper standardization and regulations towards supply chain management of sustainable hydrogen types – Mittal y Kushwaha 2024, 3.

Nowadays, approximately 95% of hydrogen energy is still based on non-renewable energies, like natural gas and coal (IRENA Green Hydrogen, A Guide to Policy Making 2020, 6). The most frequent ones include grey hydrogen, which is produced from methane or coal (WEF 2021) and blue hydrogen, which has the advantage of capturing the CO2 produced and storing it for long term (WEF 2021). Finally, turquoise hydrogen promises high capture rates (90-95%) and effective long-term storage of the CO2 in solid form (WEF 2021). Hydrogen energy will be a key tool for the green transition, hence, green hydrogen will become essential as a zero-carbon source of energy (Clarke and Wei 2022, 679).

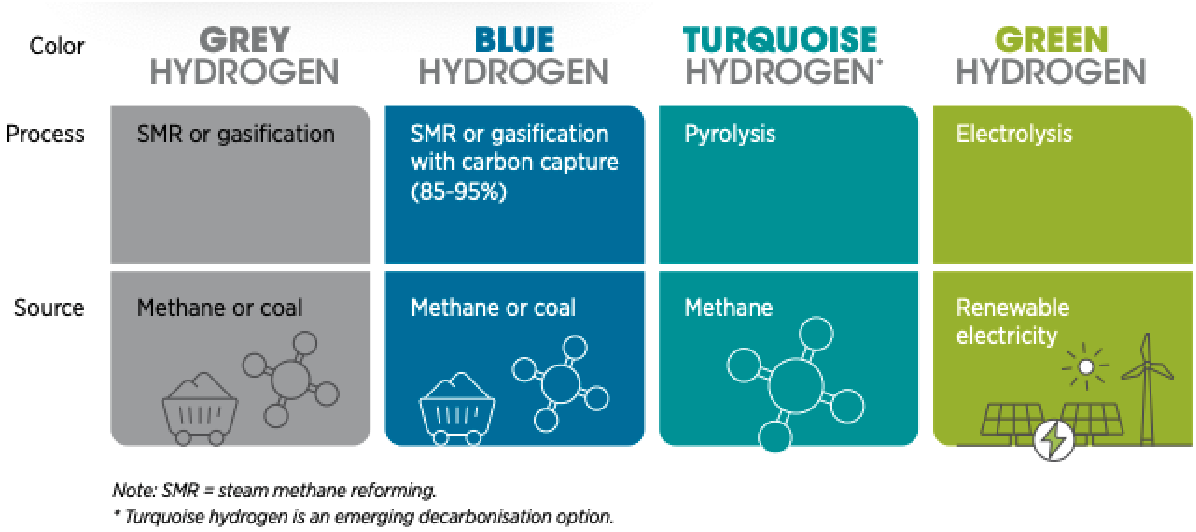

Figure 2 - Depending on production methods, hydrogen can be grey, blue or green or turquoise - WEF 2021.

2.3 Advances made with green hydrogen

Hydrogen technologies still have a long way to go to become a trending energy source, but they have great potential, what can be seen in many advances already done. Nowadays, countries are announcing strategies that support fossil-based hydrogen in the short-term, as a transitional technology for implementing green hydrogen in the long-term (IRENA, Green Hydrogen Cost Reduction 2020, 19).

Hydrogen can accelerate the energy transition by allowing clean energy to be stored and large volumes to be transported over long distances via pipelines and ships. It can foster greater resilience, cost-efficiency, and optimization at a system level. Hydrogen goes hand-in-hand with other decarbonization levers such as direct electrification, carbon capture and storage, biofuels, and energy efficiency measures (Hydrogen Council and McKinsey&Company 2022, 2).

Hydrogen energy´s potential applies to multiple purposes. First, it can help to decarbonize hard-to-abate sectors, which are known for the complexity of phase-out from fossil fuels, for instance intensive and long-haul transport, chemicals, iron and steel. Second, it helps improve air quality and strengthen energy security. Third, hydrogen increments flexibility in energy systems, owing to its versatility in supply and use, as it can be produced utilizing different energy sources. Finally, hydrogen and hydrogen-based fuels can be used to transport energy from renewable sources over long distances (IRENA 2019, 7).

There are plenty of reasons to support the implementation of green hydrogen energy. First, a major part of the costs is related to electricity, which has decreased substantially in the case of solar photovoltaic (from 250USD/MWh in 2018 to 56USD/MWh in 2018) and onshore wind plants (from 75USD/MWh in 2018 to 48 USD/MWh in 2018) (IRENA Green Hydrogen, A Guide to Policy Making 2020, 10). Second, the needed technology is becoming more accessible and ready to be commercialized, only needing investment to scale up. Consequently, electrolysis costs have fallen by 60% between 2020 and 2010, provoking a decrease in cost from USD 10-15/kg to USD 4-6/kg (IRENA Green Hydrogen, A Guide to Policy Making 2020, 10).

Third, governments worldwide aim to achieve net-zero emissions soon. In total, more than 120 countries have announced net-zero emissions goals (IRENA Green Hydrogen, A Guide to Policy Making 2020, 11). While these net-zero plans still must become practical actions, it will require cutting emissions in the hard-to-abate sectors, where green hydrogen can play an important role.

Fourth, green hydrogen can be used across many sectors of the economy. This includes additional conversion of hydrogen to other energy carriers and products, like ammonia, methanol and synthetic liquids. These uses can increase the future demand for green hydrogen taking advantage of the decreased costs in the value chain. This way, industrial competitiveness can be improved not only for technological leading countries, but also by providing an opportunity for existing industries to have a role in a low-carbon future (IRENA Green Hydrogen, A Guide to Policy Making 2020, 11). Hence, countries with greater access to renewable energies could become exporters of green hydrogen in a global green hydrogen economy (IRENA Green Hydrogen, A Guide to Policy Making 2020, 11).

Lastly, interest in hydrogen is widespread among public and private stakeholders. These include energy utilities, steel makers, chemical companies, port authorities, car and aircraft manufacturers, shipowners and airlines, and countries aiming to use their renewable resources to improve their own energy security through hydrogen (IRENA Green Hydrogen, A Guide to Policy Making 2020, 11). These many players have also created partnerships and ongoing initiatives to foster collaboration and coordination of efforts.

Green hydrogen most ambitious strategies come from the EU. In 2020 it targeted to produce 40GW by 2030 (IRENA Green Hydrogen Cost Reduction 2020, 21). Considering the importance of green hydrogen across energy sectors, the strategy was released together with the Energy System Integration strategy and the Clean Hydrogen Alliance, a platform to bring together multiple stakeholders from industry, government, civil society and academia, emphasizing the importance of cooperation and partnerships (IRENA Green Hydrogen Cost Reduction 2020, 23).

The importance that hydrogen energies are achieving cannot be denied. Every day more countries are announcing new hydrogen strategies and projects. Until December 2023, 1,400 projects were announced across all regions, equaling USD 570 billion investments and 45 million tons per annum of clean hydrogen supply announced through 2030. From these figures, Europe represents the largest number of projects (540) (Hydrogen Council and McKinsey&Company 2023, 4).

Green hydrogen will play a crucial role in achieving net-zero targets. It is estimated that its demand will reach 690 million tonnes per annum by 2050, eleven times the 2020 production. Hence, hydrogen would represent 22% of global final energy demand, with projected uses for power generation, transportation, building heat, new industries (including steel and liquid biofuels), and existing industry uses (World Bank Group and Hydrogen Council 2022, 16). Additionally, countries that have the advantage of abundant renewable power and/or carbon capture capacities will be better-placed to scale-up hydrogen production. Consequently, as Figure 3 shows, it is estimated that blue hydrogen production will increase in the near future, but in the long-run green hydrogen will be much more demanded.

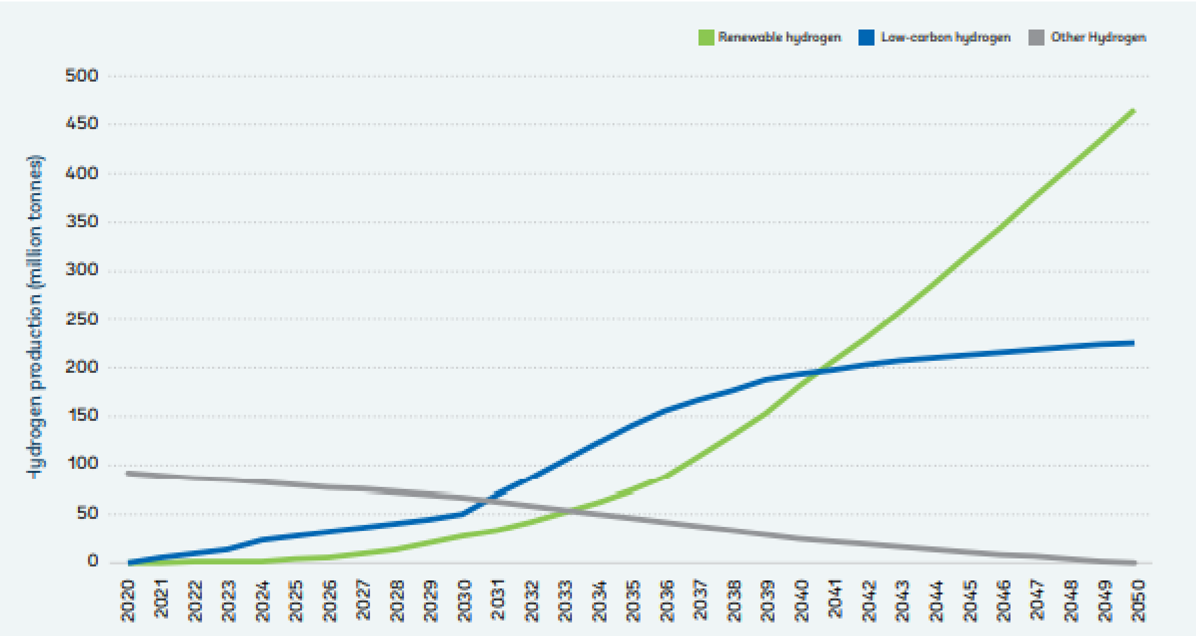

Figure 3 - Projected annual hydrogen production by production pathway - World Bank Group and Hydrogen Council 2022, 22.

2.4 Current challenges

Green hydrogen, as the rest of the new renewable energies, has its own challenges. For instance, the high cost across the entire value chain, from electrolysis to transport and fuel cells, the lack of existing infrastructure for transport and storage, the high energy losses (requiring higher wind/solar deployment rates), and the perceived lack of value for the main benefit presented (a decrease in greenhouse gas emissions) (IRENA Green Hydrogen Cost Reduction 2020, 17).

Unfortunately, the production of green hydrogen is still extremely limited to demonstration projects. In September 2020 green hydrogen contributed to less than 0.02% of global pure hydrogen production (IRENA Green Hydrogen Cost Reduction 2020, 18). The costs of production are still a major barrier, even though they have fallen since the reduction in renewable energy prices, green hydrogen is still 2-3 times more expensive to produce than blue hydrogen (IRENA Green Hydrogen Cost Reduction 2020, 8). Additionally, the cost of electrolysis still represents the second largest cost component in the production of green hydrogen (IRENA Green Hydrogen Cost Reduction 2020, 8). However, it is estimated that green hydrogen production costs can decrease by 85% in the long run by a combination of cheaper electricity and electrolyzer capex investment, added to increased efficiency and optimized electrolysis (IRENA Green Hydrogen Cost Reduction 2020, 9).

The lack of the necessary infrastructure is also a great issue to tackle. Hydrogen has been produced close to where it is used, with limited dedicated transport infrastructure. On the positive side, natural gas infrastructure could be repurposed for hydrogen usage, but not all regions of the world have the infrastructure needed for this change (IRENA Green Hydrogen, A Guide to Policy Making 2020, 13).

Another challenge is the energy loss during the value chain. Approximately 30-35% of the energy produced gets lost. Additionally, the conversion of hydrogen to other carriers (like ammonia) can result in 13-25% energy loss and transporting hydrogen can also represent the loss of 10-12% of the hydrogen energy itself (IRENA Green Hydrogen, A Guide to Policy Making 2020, 13). Consequently, the amount of energy lost will depend on the final use decided. The higher the energy losses, the more renewable electricity capacity is needed to produce green hydrogen. The next question is whether the annual pace of development of the solar and wind potential will be fast enough to meet the needs for the electrification of end-uses and a global supply chain in green hydrogen, and the cost that this additional capacity will entail (IRENA Green Hydrogen, A Guide to Policy Making 2020, 13).

All in all, today the existing hydrogen energy is almost entirely supplied from natural gas and coal. Green hydrogen production is extremely costly now, however, the costs are falling rapidly. Today hydrogen is mostly used for oil refining and to produce ammonia, while it needs to be implemented in a wider variety of industries where it is currently almost absent, such as transport, buildings and power generation (IRENA 2019, 7).

2.5 The Russian invasion in Ukraine as a breakpoint in hydrogen energy development

In 2020 the European Commission launched its Hydrogen Strategy for a Climate Neutral Europe (European Commission 2020). Here, it states plenty of benefits derived from hydrogen energy, principally based on the non-emission of CO2, but also recognizing that hydrogen represents only a modest fraction of the global and EU energy mix and is still largely produced from fossil fuels. Consequently, hydrogen was a key priority to achieve the European Green Deal and Europe's clean energy transition, as renewable electricity would contribute to decarbonize a large share of the EU energy consumption by 2050. In 2018 the share of hydrogen in Europe's energy mix was projected to grow from less than 2% to 13-14% by 2050 (European Commission 2020, 1).

In that moment, the estimated costs for fossil-based hydrogen were around 1.5 €/kg for the EU, which was highly dependent on natural gas prices while also disregarding the cost of CO2. At the same time, estimated costs for fossil-based hydrogen with carbon capture and storage were around 2€/kg, and renewable hydrogen 2.5-5.5€/kg (European Commission 2020, 4).

This first strategy established that it was a priority for the EU to develop renewable hydrogen, produced mainly from solar and wind power. From 2020 up to 2024, the strategic objective was to install at least 6GW of renewable hydrogen electrolyzers in the EU and the production of up to 1 million tonnes of renewable hydrogen, to decarbonize existing hydrogen production (European Commission 2020, 5). Later, from 2025 to 2030, hydrogen would become an intrinsic part of an integrated energy system with a strategic objective to install at least 40GW of renewable hydrogen electrolyzers by 2030 and the production of up to 10 million tonnes of renewable hydrogen in the EU (European Commission 2020, 6). Additionally, the European Clean Hydrogen Alliance would help to build a robust pipeline of investments, including the Strategic European Investment Window of the InvestEU program and the ETS Innovation Fund, to enhance the funding support and help bridge the investment gap for renewables generated by COVID-19 (European Commission 2020, 6).

In 2022, after the Russian invasion to Ukraine, the EU needed to reevaluate its previous energy strategies to earn independence from Russian natural gas. During previous years, as the production of gas inside the EU fell, Russia's share of total EU gas demand rose to an average of over 40% between 2018 and 2021 in comparison to the 26% demanded in 2010 (IEA). After the outbreak of the war in 2022, Russia cut 80 billion cubic metres of pipeline gas supplies to Europe, plunging the region into an energy crisis. While the EU was committed to phase out Russian fossil fuel imports "as soon as possible", it faced an immediate energy deficit that needed to be filled (IEA).

Consequently, the REPowerEU Plan set out by the European Commission aims to make the Union independent from Russian fossil fuels well before 2030. The communication provides for the front-loading of wind and solar energy, increasing the average deployment rate of such energies as well as for additional renewable energy capacity by 2030 to accommodate the higher production of renewable fuels. It also invited the co-legislators to consider establishing a higher or earlier target for the increased share of renewable energy in the energy mix (European Council 2023, 2). This way, the objective was to gain back energy security considering the geopolitical inconvenient caused by the start of the war (European Council 2023, 2). Moreover, the program also encourages the use of renewable fuels, including green hydrogen, obtained through electrolysis using renewable electricity (European Council 2023, 45).

2.6 Theoretical framework

To evaluate the extent of the success of Germany's and France's implementation of the new EU directive the energy trilemma framework adopted by the World Energy Council will be used.

The dimensions used by this index are (World Energy Council 2024, 76):

- Energy security: reflects a country's ability to reliably meet current and future energy demands, recover quickly from disruptions, and maintain steady energy supplies. This pillar includes the management of domestic and external energy sources and the resilience of energy infrastructure;
- Energy equity: measures the accessibility, affordability, and abundance of energy for all citizens, including access to electricity and clean cooking facilities, levels of energy consumption conducive to prosperity, and the affordability of electricity, gas, and fuel;
- Environmental sustainability: focuses on minimizing environmental damage and climate change impacts, this dimension reflects the efficiency and productivity of energy generation, transmission, and distribution, as well as efforts towards decarbonization and air quality improvement.

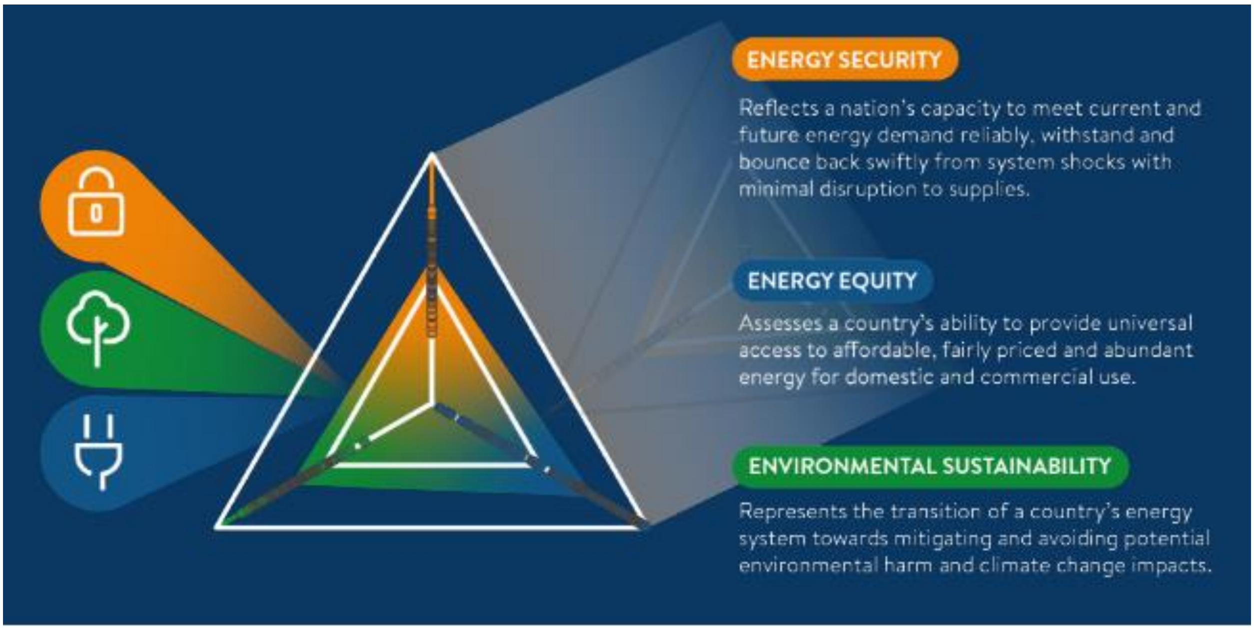

Figure 4 - Energy Trilemma Framework - World Energy Council 2024, 9

This index's objective is to quantify the challenges of providing secure, equitable and affordable, and environmentally sustainable energy to societies. A fourth dimension of country context is also analyzed to capture differences in countries' institutional and macroeconomic contexts (World Energy Council 2024, 80). For the purpose of this specific research, the country context variable will not be taken into consideration, first because of the extension of this paper, and second because the two countries analyzed do not differ considerably between each other in relation to their institutional and macroeconomic contexts.

The main objective of the index is to capture the aggregate effect of energy policies in each country, but it does not capture the effectiveness of a particular policy (World Energy Council 2024, 82). Using the world energy trilemma framework will provide a holistic approach to the analysis done in this thesis, as it considers the reliability, affordability and sustainability of the energy policies. Additionally, the EU directive also embraces these three principles, so it would be logical to expect that every country's green hydrogen strategy would be aligned with them.

Finally, these indicators will be used to analyze current policies that the governments of Germany and France have taken in response to the new EU plan, enabling the consideration of each pillar in a detailed and non-binary way.

For the purpose of this research, the research question will be: “how has the Russian invasion of Ukraine in 2022 influenced the green hydrogen policies in Germany and France?”. The hypotheses to study will be first, that both countries needed to improve and expand their green hydrogen policies as a result of the energy crisis originated because of the Russian war of aggression against Ukraine in February 2022, and second, that Germany needed to take stricter and more ambitious green hydrogen policies than France to tackle the energy crisis.

All in all, it can be seen how green hydrogen energy presents great potential to decarbonize existing energy systems, but it still needs great investment to be implemented on a large-scale. Moreover, its sustainable aspects, being carbon neutral and independent from fossil-fuels makes it a great alternative to improve energy sovereignty and the green transition.

Methodology

This research will be conducted through document analysis and doing case studies about the energy policies of the two selected countries, Germany and France regarding green hydrogen.

3.1 Document analysis

Document analysis as a research method consists of the systematic procedure for reviewing or evaluating documents that can be both printed and electronic. This method requires data to be examined and interpreted to elicit meaning, gain understanding, and develop empirical knowledge (Bowen 2009, 27). Documents usually contain text and images that have been recorded without a researcher's intervention (Bowen 2009, 27).

The documents used to conduct document analysis might take a variety of forms, including advertisements, agendas, attendance registers, and minutes of meetings, manuals, background papers, books and brochures, diaries and journals, letters and memoranda, newspapers, press releases, program proposals, application forms, and summaries, organizational or institutional reports and more (Bowen 2009, 28). Additionally, documents are useful as a means of tracking changes and developments, hence if various drafts of a particular document are accessible, researchers can compare them to identify changes (Bowen 2009, 30).

One of the advantages this method offers is the broad availability of research resources. If the topic researched is not ethically compromising or should be kept in secrecy, plenty of documents can be found in the public domain, especially since the advent of the Internet.

On the other hand, researchers must avoid falling into biased selectivity of the documents used. For example. in an organizational context, the available documents are likely to be aligned with the agenda and corporate policies and procedures. However, they may also reflect the emphasis of the particular organizational unit that handles record-keeping (e.g., Human Resources) (Bowen 2009, 32).

Document analysis can be done through skimming (superficial examination), reading (thorough examination), and interpreting the content. This process combines elements of content analysis and thematic analysis (Bowen 2009, 32). As part of the researcher's work, it should determine the authenticity, credibility and accuracy of the selected documents. It is important to assess the documents to confirm if they are comprehensive (covering the topic completely or broadly) or selective (covering only some aspects of the topic). The researcher should also determine if the documents are even (balanced) or uneven (containing great detail on some aspects of the subject and little or nothing on other aspects) (Bowen 2009, 33).

En this specific research, the primary source of documents analyzed consists of policy papers and scientific reports from international organizations dedicated to researching climate change and energy topics, for instance, the Intergovernmental Panel on Climate Change (IPCC), the International Renewable Energy Agency (IRENA), the Hydrogen Council, the Green Hydrogen Organization and the International Energy Agency (IEA). Additionally, documents from the EU and the European Commission and from the governments of Germany and France will also be taken into consideration to highlight the policy needs remarked by the EU and how they were implemented by both countries at the local level.

Moreover, secondary sources mostly coming from academic papers, and different news and environmental blogs (for example, the Clean Energy Wire – CLEW), will also be considered as a way to complement the primary sources mentioned above and with the objective of adding voices and analysis to the research.

Considering the relevance hydrogen energy has acquired during the previous years, fortunately there is a great number of scientific reports and policy papers to shed light on this topic. At the same time, these reports can be considered to be objective and based mostly on scientific evaluations and data, what makes them a solid and objective source to analyze. Regarding the secondary sources, they were extracted from impartial sources of information and renown academic journals to assure their objectivity and trustworthiness.

3.2 Case studies

Case studies seek to answer 'how' and 'why' questions from a systems approach and with the support of theoretical approaches (Ridde, Coulibaly and Gautier). Case studies can be used to explain a public policy, describing it in depth or illustrating a specific situation, which can provide extra information during the decision-making process. The advantage case studies present is their adaptability to different situations where there are multiple variables of interest around a policy (Ridde, Coulibaly and Gautier).

Conducting a case study can become increasingly complex, as many different data sources can be used for this research method, including qualitative, quantitative or mixed methods, what most often allows for a rich description of the public policies evaluated and the contexts of implementation (Ridde, Coulibaly and Gautier).

For the purpose of this research, the case studies conducted will focus on the green hydrogen strategies adopted by Germany and France after the Russian war of aggression against Ukraine on February 24th, 2022.

The reason to select these two countries is based first on the importance of both economies in the region, as they are the most powerful ones, two of the most populous in the EU and the largest energy consumers. While France boasts much lower energy sector emissions than Germany (the top emitter), they both struggle to meet national and European greenhouse gas reduction targets (Lafrance and Wehrmann, How Germany's and France's climate policies and greenhouse gas emissions compare 2023). Germany is the largest fiscal space and leading manufacturer of industrial goods (Quitzow, Nunez and Marian 2023, 4), what gives it the chance to establish as a major technology provider and importer of green hydrogen. At the same time, before the war outbreak, Germany was highly dependent on Russian oil and gas, what forced the country to stop importing Russian fossil fuel energies at a high speed – reducing oil imports from 35% to 12% and gas imports from 55% to 35% in August 2022 (Schmidt 2022).

On the other hand, France is the second biggest economy in the region, but its energy scheme is considerably different from the one-off its neighbor. The French are characterized for having the highest share of nuclear energy in their energy mix in the world and are committed to building new reactors as part of the plan to meet European climate targets and net-zero emissions by 2050 (Lafrance and Wehrmann, Lingering nuclear dissent between Paris and Berlin obstacle for EU renewables push 2023).

Consequently, Germany and France are the two most influential members of the Union, and while they agree on the urgent need to decarbonize Europe's energy system and put supply security on a safer footing, they have different opinions about the technologies that should be used to achieve these goals (Lafrance and Wehrmann, French and German energy discrepancies hamper joint EU climate strategy 2023).

3.3 Ethics

Regarding the ethical aspect of this research, conducting document analysis can also reduce the possible ethical concerns (Morgan 2022, 64). Of course, documents are not free from ethical concerns, as documents by themselves will likely not include important information that other research methods might uncover. For example, in the case of documents that are not available for the public, an organization can provide access only to content aligning with the values of its chief executives. Therefore, conducting research with documents as the sole source may raise questions about biased selectivity (Morgan 2022, 66).

Moreover, the use of pre-existing documents raises fewer ethical concerns than using other qualitative methods as public records are available for anyone to examine. Usually, authors of books and articles appearing in open sources are aware that anyone will be able to read their content, what usually reduces the ethical concerns associated with using public documents. On the other hand, this content can reflect the biases of the authors, as a newspaper may be motivated to express a political perspective rather than to report the facts objectively (Morgan 2022, 69).

On this specific case and going back to the type of documents used in this research, considering that mostly all the primary sources are scientific and policy papers from renown organizations, it is sound to believe that the ethical concerns are quite limited in this case. Regarding the sources coming from State policies, these may in any case try to show more ambitious objectives than what would be possible to reach. However, considering there are no ethically high-risk methods used in this thesis, like interviews or observations, the ethical concerns do not represent a limitation for this research.

Findings and Discussion

In this chapter, a thorough policy analysis will be conducted to explore first, the general policy framework that the EU created with the REPowerEU Plan after the outbreak of the Russia-Ukraine war. Second, the specific policies that Germany and France have announced will be analyzed and compared with the existing strategies before the war, to conclude if there was a real improvement in the green hydrogen strategies at the local level in both countries. Additionally, the new German and French policies will be examined using the energy trilemma framework to compare the positive and negative aspects of both countries and if Germany effectively took stronger measures than France.

4.1 The European Union

Russia's war of aggression against Ukraine created a shock in Europe's energy market. Consequently, the discourse and strategies surrounding renewable energies in the region shifted from a climate change focus (in line with the Paris Agreement) to an energy security and independence focus (GLOBSEC 2022, 3).

Before February 2022, Europe already had the most ambitious green hydrogen strategies (IRENA Green Hydrogen Cost Reduction 2020, 22). In 2019, the European Hydrogen Energy Roadmap identified hydrogen as a key technology for achieving the Union's climate goals and called for the development of a hydrogen infrastructure, the deployment of hydrogen technologies, and the creation of a hydrogen workforce. Additionally, it also identified green hydrogen as the preferred form of hydrogen as it is produced with renewable energy sources (Islam et al. 2024, 473).

The Green Deal, launched in 2021, was motivated on carbon neutrality, economic growth and technology leadership focused on electrolyzers. The original targets were 6GW of electrolyzer capacity by 2024 and 40GW by 2030, and production targets of 1 million and 10 million tonnes of green hydrogen per year. Reaching these production targets would require a larger capacity than anticipated, what implied the need to import more hydrogen energy from neighboring countries (IRENA Green Hydrogen Cost Reduction 2020, 23).

The war outbreak revealed the weakness of Europe's energy model, what made the EU launch REPowerEU in May 2022, a new plan to put an end to Russian hydrocarbons dependence before 2030 and to achieve carbon neutrality by 2050 (Messad 2023, Franc 2023, 4), fast forwarding the green transition and joining forces to achieve a more resilient energy system and a true Energy Union (European Commission 2022 Questions and answers on the REPowerEU Communication). The policy includes accelerating hydrogen production and implementing import strategies. The Commission's plan aims to use 20MT of low-carbon hydrogen by 2030, half from local production and half imported. These 20MT of renewable hydrogen will replace, depending on use, between 25 and 50 billion m3 of natural gas (Franc 2023, 4).

However, having the capacity to produce 10MT of hydrogen by 2030 would require the construction and installation of 100GW of electrolysis capacity, added to extensive use of renewable and nuclear energies (Franc 2023, 5). Additionally, renewable energy production targets were increased from 40% to 45% by 2030 and energy efficiency goals bumped up from 9% to 13% (GLOBSEC 2022, 5, European Commission 2022 Press Release). To achieve these supply goals electrolytic hydrogen production capacity will need to be doubled every year until 2030 (Franc 2023, 5).

To accelerate the hydrogen market, there is a need to implement additional sub-targets for specific sectors. Also, to accelerate hydrogen projects, additional funding of €200 million has been set aside for research, and the Commission committed to complete the assessment of the first Important Projects of Common European Interest. (European Commission 2022 Press Release).

As a consequence of REPowerEU, there was a major shift in the gas supply sources in the region, substituting Russian imports mostly with gas coming from Norway, the United States and UK, as can be seen in Figures 5 and 6. Additionally, oil and coal imports also registered severe reductions, going through representing 30% between 2017-2021 to 20% in 2022 in the case of oil and decreasing from 39% to 26% in the same time period for coal (Yanatma 2023).

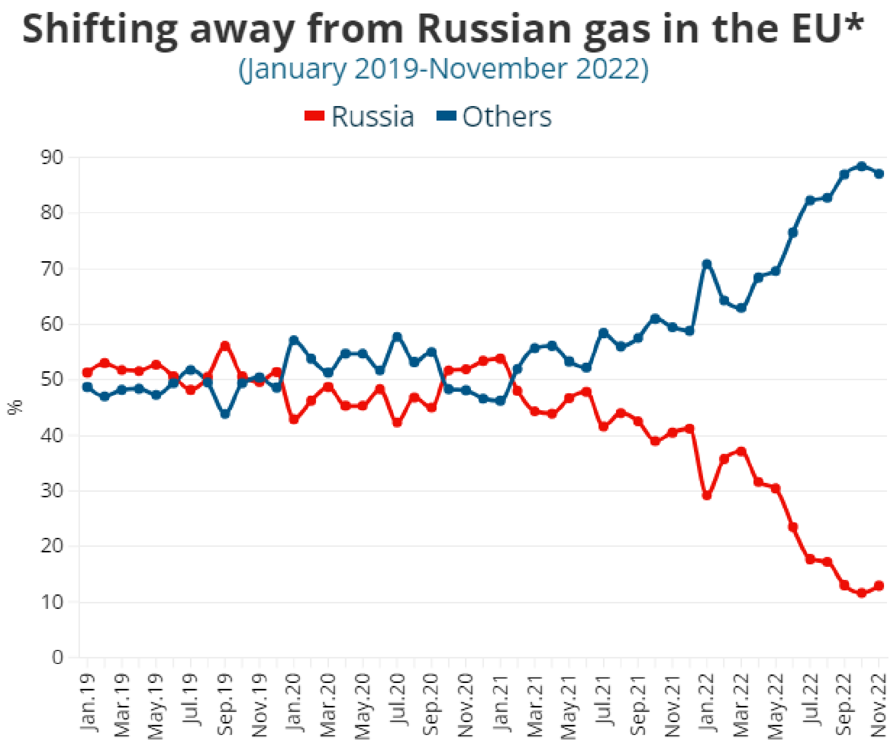

Figure 5 - Gas imports in the EU between 2019-2022 - Yanatma 2023.

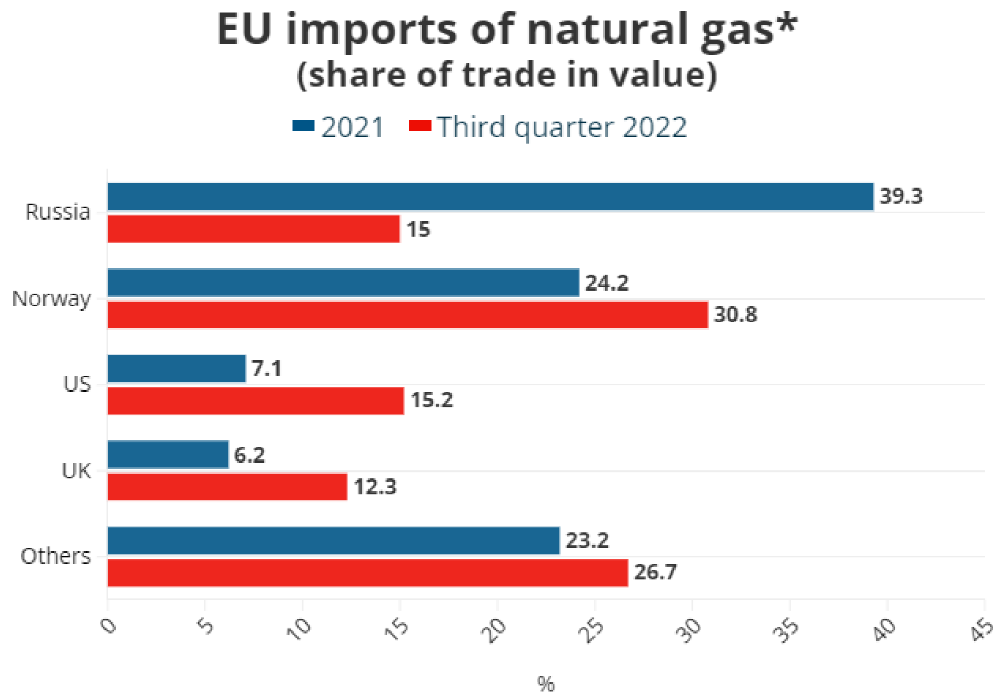

Figure 6 - Natural gas imports in the EU years 2021 and 2022 - Yanatma 2023.

REPowerEU's hydrogen objectives aim to be achieved by boosting production, accelerating pipeline projects and doubling the number of Hydrogen Valleys. These are geographical areas where hydrogen serves more than one end sector or application in mobility, industry and energy, usually needing a multi-million-euro investment and cover all necessary steps in the hydrogen value chain, from production to subsequent storage and its transport & distribution to various off-takers.

Moreover, hydrogen imports will be facilitated by a new dedicated work stream under the EU Energy Platform which should operationalize the European Global Hydrogen Facility and support green hydrogen partnerships (European Commission 2022 Questions and answers). The Commission will also support the development of three major hydrogen import corridors via the Mediterranean, the North Sea area and with Ukraine, when the conditions enable it. As a way to boost hydrogen demand, the European Commission is seeking to increase hydrogen sub-targets under the renewable energy directive and will roll-out carbon contracts for difference under the Innovation Fund (European Commission 2022 Questions and answers).

All in all, the objectives stated by REPowerEU are to save energy and improve energy efficiency, diversify energy supplies and accelerate the clean energy transition to phase-out from Russian fossil-fuel dependency (European Council, The REPowerEU plan explained).

4.2 Germany

In June 2020 Germany released its first hydrogen energy national strategy, with the objective to foster hydrogen potential towards greenhouse gas emissions neutrality and to tackle hard-to-abate sectors, promoting economic growth and competitiveness of the domestic industry (IRENA Green Hydrogen Cost Reduction 2020, 24). In that moment, the idea was to seek exclusively for the local production and import of renewable hydrogen, to promote its rapid market rollout and establish the necessary value chain within the country (IRENA Green Hydrogen Cost Reduction 2020, 24).

The initial estimations from the German government were that they would need from 90 terawatt hours (TWh) up to 110TWh of hydrogen by 2030. To cover partly the demand, there were plans to deploy up to 5GW of hydrogen generation capacity using water electrolyzers coupled to onshore and offshore wind farms by 2030, rising to 10GW in total by 2035-2040 (IRENA Green Hydrogen Cost Reduction 2020, 24, Quitzow, Nunez and Marian 2023, 6).

As hydrogen energy imports were essential to achieve the estimated targets, Norway and Australia represented two important alliances. Norway enhanced its cooperation by building on the North Seas Energy Cooperation, to improve the expansion of the offshore grid development and the renewable energy potential in the region. However, it was not until March 2022 that both countries signed an energy collaboration joint statement, establishing collaboration in blue and green hydrogen imports (Quitzow, Nunez and Marian 2023, 16).

Some of the main objectives pursued by the 2020 strategy were: 1) the establishment of green hydrogen and its downstream products as key elements of the energy transition to reduce greenhouse gas emissions; 2) the creation of a domestic market by building appropriate hydrogen production capacity and developing technologies for the use of hydrogen on the demand side; 3) implementing a regulatory framework for the development and expansion of hydrogen-based transport and distribution infrastructure; 4) strengthening the competitiveness of German companies by promoting the use, research, development and export of hydrogen technologies; 5) securing the future supply of green hydrogen and its downstream products with the help of international partnerships (The Federal Government of Germany, The National Hydrogen Strategy).

One of the bases to achieve a hydrogen economy was the reliable and sustainable production of hydrogen, which had to be provided at competitive costs. To reduce production costs significantly, it is essential to build electrolyzer plants on an industrial scale to produce green hydrogen. Simultaneously, renewable energy needs to be expanded to provide the green electricity needed to produce green hydrogen. To promote investments in hydrogen, there must also be appropriate demand for hydrogen energy on the application side (The Federal Government of Germany, The National Hydrogen Strategy).

The Russian invasion of Ukraine impacted profoundly the climate and energy policies in Germany, as a consequence of its high dependency on energy imports (Loewe 2024, 1) (The Federal Ministry of Economic Affairs and Climate Action of Germany 2022, 1). In response, a wide variety of sanctions were released, bringing big consequences for the energy market in the region, especially to Germany. During 2022, German imports of oil from Russia decreased from 34% of total oil imports to 1%, while hard coal and natural gas imports from Russia decreased from 55% to 9%, and from 40% to 0% respectively (Loewe 2024, 3).

Consequently, there was a significant shift in Germany's energy policies and discourses. First, the secure energy supply came back to the agenda, leaving aside the dominant sustainably discourse. Second, the importance of partnerships was highlighted, focusing more on the importance of hydrogen energy imports. Third, there was a redirection of the discourse towards the innovation process of hydrogen technologies, with a specific emphasis on infrastructure issues, for instance liquefied natural gas terminals that could be used for hydrogen energy (Loewe 2024, 11). Additionally, as part of REPowerEU, Germany's plan includes investments of €3.3 billion devoted to decarbonizing the economy, especially the industry, with a focus on renewable hydrogen and €1.5 billion to help the German economy make the leap towards renewable hydrogen at all stages of the value chain. including production, infrastructure and use (European Commission).

Before the outbreak of the war, hydrogen import was discussed mostly in theoretical terms, import advocates argued that importing hydrogen from countries with better renewable energy systems would lead to a reduction of costs for Germany, while also embracing climate-friendly energy supply. On the other hand, critics of hydrogen imports expressed their concerns related to new potential import dependencies, in addition to the environmental and social risks for exporting countries, and the danger of perpetuating exploitation or colonialism. However, the new discussions about energy imports and for energy and hydrogen-partnerships were prominent (Loewe 2024, 13).

In the case of the German-Norwegian Energy and Industrial Partnership, the German government is aiming to develop import infrastructures based on pipeline and ship transport, assuming that a large proportion of the demand will be covered through pipelines (The Federal Ministry of Economic Affairs and Climate Action of Germany 2022, 1). Also, as part of REPowerEU, Germany's goal is to integrate its core hydrogen network with the emerging hydrogen networks of the EU and neighboring countries, as part of the Hydrogen Hy2Infra wave (approved by the European Commission in February 2024) (The Federal Ministry of Economic Affairs and Climate Action of Germany 2022, 1).

Nevertheless, importing hydrogen energy also presents disadvantages, as part of the energy produced originally is lost during the supply chain. Hence, actions like desalinating sea water to get fresh water as raw material, conducting electrolysis and liquification for shipping, transporting via tanker, transporting locally via pipeline in Germany and finally doing the re-conversion of hydrogen into electricity in the final destination may represent a loss of up to 70% of the originally produced electricity, what later means that the need of energy imports will actually increase in comparison to locally produced hydrogen.

In addition to this, new pipeline systems require not only high initial investment, intense diplomatic effort, and years of work to be complete, but also create great path dependence owing to infrastructure rigidity (Pepe, Ansari and Gehrung 2023, 15). Compared to pipelines, ships could be more competitive, especially over long distances, as they depend less on network infrastructure, what favors global trade (Pepe, Ansari and Gehrung 2023, 15).

Additionally, the government's efforts before the war were focused mostly on green hydrogen, but after this event, blue hydrogen appeared again in the agenda, as other countries, like Canada, Norway and the UK started to push for it by injecting captured carbon into oil and gas fields for long-term storage. This plan presents great advantages at least in the short run, while Germany improves its renewable energy infrastructure, which is essential for the massive production of green hydrogen (Amelang and Wettengel 2023). However, in environmental terms this shift proposes a regression, as the focus will no longer be only on green hydrogen, but green and blue hydrogen energy, what in the long term also represents more greenhouse gas emissions. The vision of the German Government is that that natural gas-based hydrogen will eventually pave the way into a future which will be dominated by renewable hydrogen (The Federal Ministry of Economic Affairs and Climate Action of Germany 2022, 3).

The new strategy adopted after the war increased previous targets, aiming to go from 5GW to 10GW of German electrolyzer capacity in 2030 to make the country a lead supplier for hydrogen technologies (Wettengel 2023). At the same time, it estimates that between 50 and 70% of the demand would have to be covered by hydrogen imports, aiming to have 1.800 kilometers of refurbished and new pipelines ready as early as 2027/2028 (Wettengel 2023). All in all, the German government instead of relying on domestic potential for the production of green hydrogen (as it was aiming before the war), has focused mostly on imports of green and also blue hydrogen, which is much more harmful to the climate than green hydrogen as it is produced with natural gas (BEE 2023). Also, this situation puts it back again in danger of falling into new import dependency.

Finally, the European Commission has expressed its concern and recommendation to the German government to develop more detailed and quantified policies in relation to renewable energy targets. Moreover, it asked to describe how it aims to accelerate the deployment of renewables via the uptake of renewable power purchase agreements specifying the deployment of renewables and the phasing out of fossil fuels in the heating and cooling sector, including comparable measures for promoting hydrogen in industry, and preparing the EU for renewable hydrogen trade (European Commission, Commission Recommendation 2023, 7).

4.2.a Analysis using the energy trilemma framework

Energy Security

The German approach to address energy security using hydrogen is multifaceted, focusing on domestic production and international partnerships. On the national production side, it aims to increase the electrolyzer capacity by 2030 to 10GW, what would contribute in the long run to the stabilization of energy supply and reduce dependence on imports.

Regarding international partnerships, Germany is giving now great importance to alliances with countries like Norway and Australia, this can be seen as a new risk for the German energy system as the dependence on imports would still be of a considerable proportion. This way, Germany now is prioritizing abandoning Russian energies, but it seems like it is still aiming to depend on other countries, through the import of hydrogen energies through pipelines and ships.

Energy Equity

The promotion of hydrogen energy in hard-to-abate sectors would contribute to phase-out fossil fuels in many industries that need them for now, but that would also depend on the origin of the hydrogen energies, this would be expected to stimulate the economy and improve local industries, what in the long run can create more jobs and foster energy equity.

Moreover, Germany´s strategy aims to decarbonize the economy with great flows of money to advance renewable hydrogen across the value chain. Hence, this would make this energy more affordable, reducing the costs for the population. On the other hand, as I see it, it is still pending to know about the real affordability and convenience of hydrogen imports, considering the origin of the energies and the risk of losing a great part of it during the whole value chain.

Environmental Sustainability

Unfortunately, even though Germany´s energy policies are aligned with their climate objectives to reduce carbon emissions and reach carbon neutrality in the near future, the latest policies adopted have shown a potential regression in this topic.

Before the war, Germany´s hydrogen strategies were focused on the promotion and adoption of green hydrogen, while now they accept also blue hydrogen and are embracing cooperation with countries like Norway, which produces mostly blue hydrogen, using gas. It sounds logic to use this energy at least for the moment until the renewable energy structure is better equipped to produce the amount of green hydrogen needed, but policy makers should be aware of the risk of failing to achieve the long-run environmental objectives if they do not start promoting green energies urgently.

4.3 France

France was one of the first countries to present a national hydrogen strategy in 2018. Afterwards, in September 2020, a new National strategy for the development of decarbonized and renewable hydrogen in France was launched, setting the next priorities: 1) decarbonizing industry by developing a French electrolysis sector that would have capacity for 6.5GW of electrolyzer capacity by 2030; 2) developing the use of decarbonized hydrogen for heavy-duty mobility; 3) supporting research, innovation, and skills development to promote the uses of tomorrow. Additionally, in October 2021, the Plan France 2030 was announced, which had as one of France´s main objectives to become a decarbonized hydrogen leader by establishing two factories by 2030 and using hydrogen to reduce industry emissions with 35% by 2030. (Green Hydrogen Organization, France, France Hydrogene 2023, 4). In this new strategy, hydrogen technologies were considered essential for the decarbonization of the industry and transport sectors and to rebuild France's industrial competitiveness (Bouacida 2023, 4).

Moreover, the Hydrogen Ordinance from February 2021 aims to promote the French hydrogen sector development. It established that to qualify as renewable hydrogen, the energy must be produced: 1) either by electrolysis using electricity produced by renewable energy sources or by any other technology using exclusively one or more renewable energy sources, and 2) whose production process does not exceed a greenhouse gas emission threshold (Green Hydrogen Organization, France).

Nowadays, Germany and France are the most populous and powerful economies in the region, but France´s policies put more emphasis on lower greenhouse gas emissions than Germany, mostly because of nuclear energy (Lafrance and Wehrmann How Germany's and

France's climate policies and greenhouse gas emissions compare 2023), which Germany does not support, what made it close its last nuclear reactor in April 2023 (Federal Office for the Safety of Nuclear Waste Management of Germany 2024).

After the war outbreak, France presented its Green Industry bill in May 2023, which looked at ways to decarbonize the heavy industry using carbon-free hydrogen to cut in half greenhouse gas emissions by 2030 (Messad French hydrogen industry worried about national strategy update 2023). Still, the official new hydrogen strategy has not been released, but there is plenty of information from secondary sources and official announcements that give a certain idea about France´s next steps.

First, it seems like production targets would remain equal for 2030, but the new strategy would aim to enable a fast implementation to ensure the deployment of hydrogen energy in an abundant and competitive way in all the French industrial areas (Messad French hydrogen industry worried about national strategy update 2023).

Second, France recognizes that the need for green hydrogen reinforces the need for renewable and nuclear powers to produce the former. Hence, the support for the production of green hydrogen will not be truly efficient without being accompanied by an increase in renewable electricity production capacity (Franc 2023, 6). Hence, it is estimated that by 2030 solar energy capacity will have to increase by almost a third, onshore wind power by 10% and offshore wind power by 50% (Franc 2023, 6). However, achieving these objectives will not be easy as the available time is tight, and these projects are often complex to implement, while they also have high costs (Franc 2023, 6).

Also, France recognizes that it will have to replace the remaining oil and gas sector with other renewable energies, as nuclear power to be strong enough to replace the share of fossil fuels needed (Franc 2023, 6). This implies using alternative and more efficient sources of hydrogen, taking advantage of the initiatives that are gaining power in the region (Franc 2023, 6).

France´s main objectives in terms of hydrogen energy now are related first, to continue with the deep decarbonization of the economy, and second, to push for the reindustrialization of the economy (France Hydrogene 2023, 2). Consequently, maintaining these two objectives will help to improve France's energy independence and industrial sovereignty. Additionally, they both go hand in hand, as a large-scale decarbonization of the most polluting economy sectors will foster French energy independence and industrial sovereignty (France Hydrogene 2023, 2).

Moreover, France aims to keep the 6.5GW target of low-carbon electrolytic hydrogen for 2030 and increase it to 10GW in 2035 (Miccoli 2024). The production would be done using French low-carbon electricity mix, renewable electricity and nuclear power. To achieve this, the government would spend €4billion on subsidies to support the deployment electrolytic production over the next three years (Collins 2023). Additionally, the idea of importing hydrogen is also a possibility, as some studies are being done about it, focusing on carbon-free hydrogen, but still the priority is to work on the local production (Collins 2023). Recently, in March 2024, the European Commission has approved a €900 million aid scheme to support the French production of energy from biomass and renewable hydrogen, as part of the Transition Framework, which seeks to accelerate the rollout of renewable energies, including renewable hydrogen (European Commission 2024). In total, the French government has promised to invest €9.2 billion in the hydrogen sector by 2030 (Boucly 2023).

As part of REPowerEU, that has as one of its main objectives to support renewable hydrogen and the decarbonization of the industrial sector, Frances expects to receive €1.7 billion to invest in low carbon and renewable hydrogen technologies (European Commission).

4.3.a Analysis using the energy trilemma framework

Energy Security

France's hydrogen strategy aims to tackle energy security giving a predominant role to national production of green hydrogen, instead of relying on imports. The objective to achieve 6.5GW of electrolyzer capacity by 2030 mostly based on local renewable electricity and nuclear power is extremely ambitious and contributes to the objective of obtaining energy independency from Russia and also other countries.

On the other hand, the introduction of instruments like the Green Industry Bill are useful to continue on the right path to promote and embrace green energies, but the fact that more than two years have passed since the outbreak of the Russian invasion in Ukraine and there is still not a consolidated new green hydrogen strategy is worrisome, considering that time to take action is tight.

Energy Equity

France´s focus on developing technologies to become a green hydrogen hub, while fostering industrial competitiveness is the core of the French current policies. The objective of establishing hydrogen factories will create new jobs for the people and promote economic prosperity, which enhances energy equity.

Moreover, there is a great list of investments already being executed or promised to improve the green hydrogen infrastructure in France, what is expected to reduce production costs and make energy accessible and affordable.

Environmental Sustainability

French strategies are aligned with the climate goals of promoting decarbonization and renewable energy integration. The known plans tend to give priority to green hydrogen over the other hydrogen energies, and the importance of renewable energies to phase-out from fossil fuels is always present in French policies, in addition to the importance of local production.

Also, by 2030 France aims to cut greenhouse gas emissions by 50% by changing the energy scheme from heavy industries. Finally, the constant support for research and innovation is key in French policies and ensures continuous improvements in efficiency and sustainability, what will reduce environmental impact.

Conclusion

The present thesis aimed to answer the following research question: "how has the Russian invasion of Ukraine in 2022 influenced the green hydrogen policies in Germany and France?". Hence, it explored the trigger that the Russian war of aggression against Ukraine represented for the development of green hydrogen energies, specifically in Germany and France. Conducting a thorough document analysis and detailed case studies, it has been demonstrated that the geopolitical event mentioned has worked as a trigger to promote research, collaboration and partnerships in the European level, to improve large-scale implementation of this new energy to combat climate change while assuring energy independence and sovereignty.

Hydrogen energy in general, and green hydrogen in particular, still have a long way to go. It is undeniable that green hydrogen will become an essential component to combat and adapt to climate change, first because it is an energy that does not provoke greenhouse gas emissions during its production, and secondly because it is fossil fuel independent, as the electrolysis process is supported by renewable energies like solar and wind power. For now, the notorious cost reduction in these last energies has made green hydrogen more accessible, but it is still not competitive in comparison to other energy sources. Additionally, hydrogen energy presents the advantage that it can be implemented, with the right infrastructure, in hard-to-abate sectors, meaning economic activities that are not easy to decarbonize. For all these reasons, it is estimated that hydrogen energies in general, and green hydrogen in particular will be extremely demanded in the future, once the needed technologies are created and adapted to be implemented in a large-scale scenario.

However, when analyzing green hydrogen large-scale implementation, many challenges appear for the moment. Some of them are related to the costs of the value chain. Also, to produce green hydrogen it is essential to count on a powerful flow of renewable electricity for conducting electrolysis, so it is necessary to previously reinforce these systems, whether using nuclear, solar or wind power. Additionally, there are still many challenges related to the import of hydrogen energy, as a great fraction of the energy is lost in the process, what ends up generating more production to compensate for the losses.

The Russian invasion of Ukraine in February 2022 constituted a breakpoint in European energy policies. First, there was a notorious change in the discourses, as before 2022 the green and energy transitions were always associated with combating and mitigating climate change. After this event, the main objective to foster and promote the energy transition at the European Union level was to phase-out European dependence on Russian oil and gas and to acquire more independence and sovereignty. As part of this political shift, REPowerEU was launched, to eliminate European dependence on Russian hydrocarbons before 2030 and achieve carbon neutrality in 2050.

As a consequence, in March 2022 the European Commission was trusted to create REPowerEU to implement the region's phase-out from Russian energies by improving energy efficiency and renewable energy development. REPowerEU was launched in May 2022.

It is interesting to see also the different priorities and approaches that both, Germany and France took to comply with EU's directive to incentivize renewable energies. In the case of Germany, the country took quick action to diversify its energy sources and gave great importance to hydrogen energy imports from various countries. At the same time, the policies that before were more focused on carbon-free energy, like green hydrogen, saw a regression with the outbreak of the war, as great importance was given to blue hydrogen, leaving aside the greenhouse gas emissions produced during the value chain and the energy used to conduct electrolysis.

On the other hand, the French government has seen the war as an opportunity to strengthen and renovate its energy system, based mostly on local resources, while also pushing its own economic development and industrialization. Improving the national energy system and aiming to become a green hydrogen hub for Europe and the world is clearly a great objective to have in terms of public policies, prioritizing research and innovation and industrial competitiveness. However, it is worrisome that after more than two years since the outbreak of the war there is still no official new strategy that frames, contextualizes and gives clear steps to follow in the future to promote green hydrogen.

After analyzing both countries policies using the energy trilemma framework, it can be seen how the two countries have positive and negative points in their green hydrogen policies as a response to the REPowerEU Plan. In the case of Germany, there is still a great dependence factor in terms of hydrogen imports, what affects the security aspect of it, added to the environmental regression of promoting blue hydrogen when before the focus was done more on green hydrogen for being the best option environmental terms. In the case of France, it can be seen how the three pillars of the trilemma framework show better results, but what catches the attention is the delay to adopt a new official strategy that gives a more comprehensive framework to the energy transition.

Consequently, after conducting a thorough analysis of both countries green hydrogen policies it can be concluded that the first hypothesis ("both countries needed to improve and expand their green hydrogen policies as a result of the energy crisis originated because of the Russian war of aggression against Ukraine in February 2022") can be confirmed, as both of them actually adopted stricter measures to improve their research capacities and green hydrogen production and/or import. Regarding the second hypothesis ("Germany needed to take stricter and more ambitious green hydrogen policies than France to tackle the energy crisis") it can be said that it is partially true, as on one side Germany took more measures than France, but when applying the energy trilemma framework, it can also be seen that energy security and energy sustainability are in delicate situations, as there is still great dependence on hydrogen imports, and at the same time blue hydrogen has become more accepted than before, opening the door to the possibility of leaving green hydrogen aside in favor of other hydrogen energies.

The research limitations in this case are related to the scope of the energy analyzed. As it was explained at the beginning, hydrogen energy has different colours and shades (green, blue, grey, turquoise, pink, etc.), but green hydrogen is the most sustainable one. Hence, a more comprehensive analysis could be conducted in the future to see the impact of the Russian war of aggression against Ukraine and the development of all these different energies and their interconnections. Additionally, this research has also been limited to the public announcements and strategies that government have released since February 2022, but, as it is known that governments sometimes promise more than what they can actually do, it would also be relevant to study the percentage of accomplishment of these different policies and if they were done in the targeted years. Finally, conducting the same research with least developed countries could also be interesting to see how governments with less economic and technological resources can aim to implement these new and expensive technologies.

To sum up, it can be seen how the Russian invasion of Ukraine showed the vulnerability of the energy system in the region because of its great dependence on external sources, acting as a breaking point in energy policies. Before, green energies were approached only as a matter related to climate change and green transition, but after the outbreak of the war, green energies also became a way to enhance energy sovereignty.

From a policy perspective, this crisis brought the opportunity to reinforce investments and research into this topic. At the same time, it has been shown that to use green hydrogen on a large-scale, it is also necessary to invest in improving other energy systems first, in addition to transport systems, including ships, pipelines and batteries. Hence, it is key to promote investment in scientific research and international cooperation to accelerate the shift towards green energies and energy independence, hopefully sooner than later.

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